MECHANICAL TRIPPING OF ALFALFA FLOWERS

by

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INTRODUCTION

Variability in seed setting continues to be the greatest problem in alfalfa seed production in the state of Kansas. Nevertheless the production of alfalfa seed is big business in the state. According to Grandfield and Franklin (1952) the average annual production of alfalfa seed in Kansas (1940-49) was 210,000 bushels valued at from three to six million dollars annually.

Alfalfa seed production in Kansas has been a hazardous and uncertain farm operation. This is revealed in the reports of the Kansas State Board of Agriculture, which show that the seed yields for the state have varied from 19,500 bushels in 1927 to 448,000 bushels in 1946.

Some of the factors which make the production of alfalfa seed in Kansas so uncertain are the amount of rainfall, the wind, and the weather in general. However, even when the weather is favorable there is still the pollination and seed setting of the plant to be considered. There are still differences of opinion regarding the relative importance of automatic and insect tripping.

Tripping may be defined as the release of the staminal column from the keel of the flower. The staminal column includes the style, stigma, and part of the ovary enclosed or surrounded by the 10 stamens and diadelphous filaments. This release must take place when the flower is in a turgid condition and thus it is accompanied by an explosive force as though a spring under tension is released.

Through the years, alfalfa seed producers have had to depend upon the natural tripping agents, such as insects, wind and the weather in general. Several research workers have indicated that bees are the principal trippers

of alfalfa flowers. However, there seems to be some controversy over the relative importance of each of the different types of bees as alfalfa flower trippers.

The alfalfa flower is not easily tripped. Therefore, if the insects are after pollen, they are apt to go to other plants where it may be more easily obtained. If we must depend on insects for tripping and pollination then competition between alfalfa, corn, sorghums, and sweet clover, or between alfalfa and wild flowers such as the sunflower, Spanish Needle, broomweed, smartweed, chickory, gum weed, basswood, etc. will be a factor in determining seed yield. This would be particularly true if the weather conditions at the time the alfalfa is in bloom are unfavorable for insect activity. A machine that would satisfactorily trip and cross-pollinate alfalfa flowers would remove the risk of being short of insects at blooming time, because of bad weather, from among the alfalfa seed producer's many problems.

There are two principal reasons why mechanical tripping of alfalfa flowers has not seemed feasible previously. New alfalfa flowers are developing all of the time over an extended blooming period and they are in prime condition for fertilization from only one to three days. To trip them all at the right time would necessitate going over the field a large number of times. In the second place, unless the machine were constructed so that a large amount of crossing occurred, the self-fertilization resulting from such tripping would cause less seed per flower and lower vigor of growth of the resulting progeny than would result if the same flowers were cross-pollinated.

Tripping and cross-pollination are necessary for seed production, as indicated by Tysdal (1940). Bees do not work just to accomodate the seed

grower; they are trying to store food supplies for future use. Tripping is incidental to the gathering of nectar or pollen. The bee inserts its head into the blossom and when the blossom trips the bee's head is caught between the standard petal and the sexual column and a mass of pollen is deposited on the rear of the bee's head as shown in Plate I.

At the same time that this mass of pollen is being deposited on the bee's head, some foreign pollen from previously visited flowers will settle on the sexual column of the flower. If foreign pollen comes in contact with the stigma, both the foreign pollen and the flower's own pollen will germinate; but the germ tube of the foreign pollen will develop faster and reach the ovule first, producing cross fertilized seed. It is in this manner that alfalfa is normally cross-pollinated in the field.

Mechanical seed trippers have been tried from time to time in the hope of overcoming seed yield fluctuations. These mechanical trippers have never proven successful. Several of the mechanical trippers tested have successfully tripped the flowers but have been unable to obtain a high percentage of cross-pollination. Evidence from previous experiments by Tysdal (1940), Brink and Cooper (1948), Jones and Olsen (1943), and Silversides and Olsen (1941) appears to be quite conclusive in demonstrating that a much higher percentage of pods and up to three times as many seeds per pod develop from cross-pollinated, compared with self-pollinated flowers.

Since alfalfa seed production is so important in large areas of Kansas and since information on factors mentioned earlier was lacking for this area a study was undertaken to determine the feasibility of a mechanical tripper with regard to increased production of seed and harmful or beneficial results on the plant and seed by use of a mechanical tripper.

EXPLANATION OF PLATE I

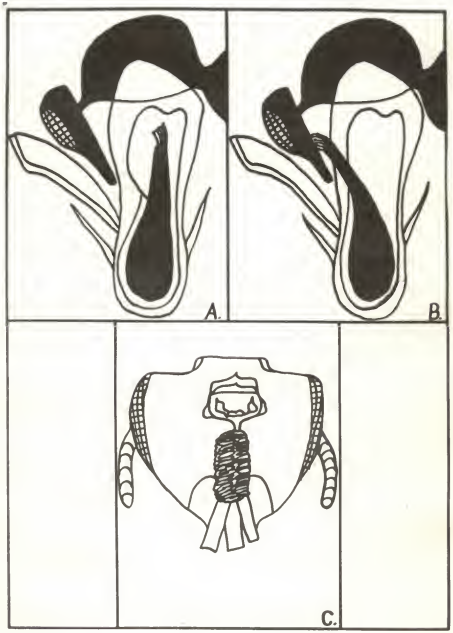
Plate I shows a bee tripping and cross-pollinating an alfalfa flower.

A. A honey bee inserts its head into an alfalfa flower to collect nectar.

B. The flower trips and the bee's head is caught between the standard petal and the sexual column.

C. A mass of pollen is deposited on the underneath side of the bee's head. This pollen will be carried to the next flower and as the flower trips, cross-pollination will take place.

PLATE I



REVIEW OF LITERATURE

Pharis and Unrau (1953) reported that a study was undertaken to determine the effectiveness of a locally built mechanical tripper and of leaf-cutter-bees, bumble bees, and honey bees in bringing about tripping and seed setting in alfalfa. Automatic or mechanical tripping followed by self-pollination resulted in 31.6 percent of pod formation, and 1.7 seeds per pod. When tripping was accompanied by cross-pollination 74.8 percent of the flowers formed pods and these pods contained an average of 4.7 seeds. Bumble and leaf-cutter-bees tripped 90.2 and 61.0 percent, respectively, of the flowers under observation. In both cases, the pods contained on the average 4.5 seeds which is proof that these bees cross-pollinated when they tripped the flowers. Honey bees were not quite as effective in tripping but most of the flowers that were tripped by them were cross-pollinated.

A single passage over each of two fields with a tripping machine, tripped 28.2 and 46.3 percent, respectively, of the flowers that were open at the time. Of these tripped flowers, however, only a small proportion formed seed, and the number per pod was similar to that obtained from self-pollination. No mention was made of injury to the flowers treated by the machine. The machine was found to be ineffective in increasing alfalfa seed yields.

An article by Goff (1952) states that a new pollinating machine was tried out successfully in 1952 on 16 farms in Minnesota and South Dakota. Farmers were reported to have watched with amazement as two to three times the usual amount of seed poured from their combines as the treated fields were harvested.

No mention was made in this article of whether cross-pollination was being accomplished or whether most of the seed was self-pollinated. At the

time this thesis was being prepared there was no data available on this machine as no scientific tests had been reported.

Silversides and Olsen (1941) reported in 1941 that a number of mechanical devices used in an effort to induce tripping on a large scale and thereby increase seed setting met with very little success. Although the number of flowers tripped was increased in nearly all cases, the amount of seed set was less than in the untreated checks due, undoubtedly, to damage of the plants and flowers by the treatment.

Mutilation of individual flowers appeared to have a marked effect on seed setting. They reported, however, that artificial tripping of individual flowers followed by cross-pollination increased sharply the amount of seed set.

Brink and Cooper (1948) have shown that fertilization can occur without tripping. Other workers, Jones and Olsen (1943), Knowles (1943), Pederson and Todd (1948) and Tysdal (1940), however, have shown that insignificant amounts of seed were produced from untripped flowers under field conditions. Though none of the machines used for mechanical tripping proved successful, all workers agree that tripping followed by cross-pollination invariably results in an increase in seed production over comparable untripped flowers, thus substantiating the conclusion that tripping is beneficial for seed production.

Tysdal (1940) states that although tripping may not insure seed production, at least seed will not be produced to any great extent without tripping. Foreign pollen is the effective agent, 80 to 98 percent of the time, in alfalfa. In addition to the higher percentage of pods being formed upon cross-pollination, a larger number of seeds are formed per pod from the cross-

pollinated than from self-pollinated flowers. Approximately 36 percent of the self-pollinated flowers set seed pods with an average of 2.44 seeds per pod. In cross-pollinated flowers 60 percent formed seed pods with an average of 3.8 seeds per pod. Considering both the percentage of flowers forming pods and number of seeds per pod, the cross-pollinated flowers produced almost exactly three times as much seed.

Tysdal, Kiesselback, and Westover (1942) state that after only one generation of self-pollination the yield of seed and forage from alfalfa had dropped to 62 to 68 percent respectively, as compared with cross-pollinated plants. After eight generations of self-pollination the production of seed and forage had dropped to 25 and 37 percent respectively.

Grandfield and Franklin (1952) have reported that honey bees were the principal insects responsible for alfalfa seed production. They stated that while their efficiency was low, their population in an alfalfa field in full bloom was often very high. Surveys have shown that it was not uncommon to have two to six bees per square yard. That would mean 10,000 to 30,000 bees per acre under favorable conditions at all times through the working day. At their normal rate of visiting flowers, they would visit 144,000,000 to 432,000,000 flowers per acre in one day. The honey bee will trip about two percent of the flowers they visit.

Over a good blooming period of 20 days, a population of one bee per square yard would trip enough flowers to make a potential production of 120 pounds of seed to the acre. This, plus other tripping that is done by wild bees, etc. could bring the yield up to double the Kansas average of 1.28 bushels per acre. These data only emphasize the importance of having a high bee population in alfalfa fields or of developing a mechanical means of tripping the alfalfa flowers.

PLANS AND INFORMATION FOR CONSTRUCTING AND OPERATING MECHANICAL ALFALFA TRIPPERS

To obtain information for this part of the investigation, a test model of a mechanical tripper, which will be hereafter referred to as the K.S.C. Tripper, was built. The construction of the K.S.C. Tripper and the related study of other similar trippers revealed many of the problems connected with mechanical tripping equipment. Plates II, III, and IV illustrate various features of the K.S.C. Tripper.

Before the construction of the K.S.C. Tripper could be started it was necessary to decide upon a tripping mechanism. From reports on previously constructed machines it was decided that rollers covered with a one inch layer of foam rubber would be used for this purpose. In order to facilitate the passage of the vertical rollers, through densely tangled alfalfa under field conditions, it was decided that the rollers should not be over six inches in diameter and 18 inches in length.

These rollers could have been of almost any material such as wood, solid metal or sheet metal tubes. The rollers used on the K.S.C. Tripper were made by constructing a hollow tube of sheet metal four inches in diameter. Circular steel plates were welded to both ends and a five-eighth inch cold rolled steel round rod was placed through the centers of these plates and welded in place. A V-belt sheave was fastened to the upper end of this round rod so that rubber V-belts could be used to drive the rollers. The rollers were then complete except for the foam rubber covering. A sheet of foam rubber one inch thick was purchased from a local furniture repair shop. The foam rubber sheet was cut to size and glued around the rollers. As the rollers themselves were four inches in diameter and the foam rubber was one inch

the completely covered rollers were six inches in diameter.

The foam rubber was fastened securely in place by gluing it to the sheet metal rollers. However, it became evident that the foam rubber was rather easily torn so heavy canvas bands were sewn tightly around the foam rubber. This gave it an adequate amount of protection for our purposes.

After the rollers were designed and built it was necessary to mount them in some manner so they could be utilized. Two wire spoke wheels, resembling bicycle wheels, were obtained and these with an angle iron framework were used to mount the rollers in place. A V-belt sheave was attached to one wheel as it was planned to use the ground wheel to supply power for the rollers. A short jackshaft and three V-belt sheaves were used to complete the drive from the wheel to the rollers. The speed of the rollers could be adjusted by changing the diameter of the V-belt sheaves in the drive. It was also possible to have the two rollers turning at different speeds by changing the size of the V-belt sheaves that controlled their speed even though both rollers were powered from the same ground wheel. It was determined that the rubbing action between the two rollers when they were turning at slightly different speeds increased the tripping efficiency of the machine.

The machine as described above tripped a satisfactory percent of the alfalfa flowers but had no provision for cross-pollination. As previously mentioned in the introduction and in the review of literature, cross-pollination is necessary for seed production. Nearly all of the mechanical trippers that have been constructed and tested have failed to be successful because they could not provide for cross-pollination.

To provide for cross-pollination when the flowers were tripped by the K.S.C. Tripper a small blower was mounted on the machine just above the

EXPLANATION OF PLATE II

Plate II shows the K.S.C. Tripper as it appeared during the experiments at the Kansas State College Agronomy Farm. This tripper was used to get the information given in Table 1.

PLATE II

EXPLANATION OF PLATE III

Plate III shows the K.S.C. Tripper with the functioning parts of the tripper visible. The large pollen chamber was mounted in front of the tripping rollers. The small door in the side of the pollen chamber was used to hold the glass slides during the pollen tests. The foam rubber rollers and the blower were powered by the small gasoline engine.

PLATE III

EXPLANATION OF PLATE IV

Plate IV shows a view of the back of the tripping rollers. Two vacuum attachments were mounted directly behind the rollers to pick up the released pollen from the tripped flowers. Hoses connected these vacuum attachments to the blower where the pollen laden air was forced into the top of the pollen chamber and then allowed to settle down onto the flowers at the bottom of the pollen chamber.

PLATE IV

rollers. A gasoline engine of one and one-half horsepower in size was mounted behind the blower and used to drive the blower with the aid of a rubber V-belt. Rubber hoses were connected between the intake side of the blower and vacuum attachments located just behind the rollers as shown in Plate IV. When the blower is in operation a suction is created through these hoses to the vacuum attachments behind the rollers. As the tripped flowers emerge from the rollers some of the pollen grains are sucked from the flowers up through the vacuum attachments and hoses into the blower. After it was determined that it was possible to pick up some of the pollen grains in this manner, there remained the question of just what to do with these grains of pollen.

Most of the machines that had been built up-to-date had taken any pollen that they picked up and passed it back onto the flowers that had already been tripped. After studying the fertilization habits of the alfalfa flowers it seemed that this might have been the wrong approach to the problem of cross-pollination. If there is no foreign pollen on the standard petal of the alfalfa flower when the flower is tripped its chances of ever being cross-pollinated are greatly reduced. In the case of cross-pollination of alfalfa by insects, this is not true as the insects have foreign pollen on that part of their bodies which is caught between the sexual column and the standard petal. In mechanical tripping there is no way to suspend these pollen grains between the standard petal and the sexual column so the next best thing is to place the pollen grains on the standard petal where the sexual column will come in contact with them when the flower is tripped. If foreign pollen could be placed on the standard petal before tripping the flower, cross-pollination would be accomplished nearly 100

percent of the time. Grandfield and Franklin (1952) stated that if the stigma is exposed simultaneously to foreign pollen and to self-pollen, the foreign pollen will develop faster and reach the ovule before the self-pollen. This fact works in favor of the mechanical alfalfa tripper so the main problem of the tripper is to get foreign pollen on the flower before it is tripped.

In order to transfer the pollen grains from the blower to the flowers just before they go into the tripping rollers, a large air chamber was constructed of a light gauge sheet metal. This chamber will be referred to as the pollen chamber. The pollen chamber was constructed so that the pollen bearing air from the blower was forced into the top of the chamber through a small opening and then allowed to spread out in the large chamber. This slowed the velocity of the air enough to allow the pollen grains to settle out and drift down onto the flowers at the bottom of the pollen chamber.

In this manner it was possible to transfer the pollen picked up from behind the tripping rollers to the flowers just in front of the rollers. This foreign pollen on the flower before it was tripped seemed to be the answer to the cross-pollination problem.

At an early test it was discovered that there was not enough traction on the ground wheel to furnish a positive drive for the rollers so a gear reduction system was mounted behind the engine and connected to it with a rubber V-belt. This gear reduction system was then used as the source of power to drive the rollers. This insured a positive drive and increased the tripping efficiency of the machine.

INVESTIGATION OF THE EFFECTS OF A MECHANICAL TRIPPER ON ALFALFA FLOWERS

Equipment Used to Trip the Flowers

Just before tests were started with the K.S.C. Tripper, another mechanical tripper that had been constructed by a private individual, became available to be tested. It was decided that the two machines would be tested at the same time in the same fields. This second tripper will be referred to in this thesis as the Chepil Tripper.

The Chepil Tripper operated on an impact principle. It consisted of a series of paddles or beaters that oscillated on a horizontal plane at high speeds. These paddles or beaters simply batted the alfalfa flowers back and forth in an attempt to trip them. Since a large quantity of air was moved by these beaters, it was thought that enough pollen would be scattered over the flowers being tripped to make it unnecessary to add further provisions for cross-pollination. Plates V, VI, and VII show this machine in more detail.

Test Procedure in Tripping the Flowers

It was necessary at this time to determine just what tests were to be made and exactly how these tests should be conducted to obtain the best possible results. Dr. C. O. Grandfield, Alfalfa Investigator, United States Department of Agriculture, was very helpful in supplying information on the best tests to make. Dr. H. C. Fryer, Professor of Mathematics, in charge of the Statistical Laboratory, Agricultural Experiment Station, Kansas State College, was consulted on how to conduct the tests. Dr. Fryer supplied information on the number of tests, the number of plants in each test, and

EXPLANATION OF PLATE V

Plate V shows the Chepil Tripper as it appeared during the tests on the Kansas State College Agronomy Farm. This was an impact type tripper and relied on rapidly oscillating blades or beaters to trip the flowers.

PLATE V

EXPLANATION OF PLATE VI

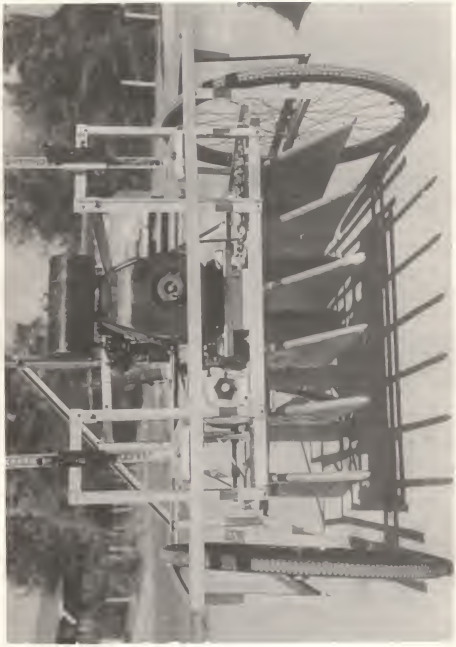
Plate VI shows the Chepil Tripper as seen from a side view.

PLATE VI

EXPLANATION OF PLATE VII

Plate VII shows the Chepil Tripper from a front view. The blades or beaters that do the tripping are hinged to the back end of the divider boards visible from the front. The divider boards were used to separate the alfalfa into rows so that approximately the same amount of alfalfa passed between each set of beaters.

PLATE VII



the number of times each test should be repeated in order for the results to be representative.

The final test procedures to be followed in our experiments were as listed below:

1. Test plots six feet wide by 100 feet long were marked off in a field of Buffalo Alfalfa on the Agronomy Farm.

2. One hundred racemes were tagged at random in each plot that was treated with the Chepil Tripper just before the treatment was given. As the K.S.C. Tripper treated a swath only about six inches in width through the plot, it was necessary to keep the tagged racemes along this swath. In order to facilitate this, a string was stretched from one end of the plot to the other end and the 100 racemes were tagged at random from the racemes along this string.

3. Before each treatment, all flowers that were already tripped or were too immature to be tripped were removed from the tagged racemes. The number of flowers left on the racemes were counted and recorded on the tags located on the racemes.

4. The plots were treated with one of the machines.

5. After the treatment the flowers that were tripped were counted and recorded on the tags. All of the untripped flowers were removed from the raceme. This left only the flowers that had been tripped by the machine.

6. Approximately one week after treatment the seed pods on each tagged raceme were counted and recorded on the tags.

7. All the tagged racemes were harvested when the seed was mature and the number of seeds per pod was determined.

8. Check plots were left at each end of the test field and between the

test plots. The same number of racemes were tagged and checked in the check plots. It was impossible to determine the number tripped by natural means, but it was possible to count the number of flowers at the start of the tests and then the number of these that set seed pods and the number of seeds per pod.

The data to be determined included:

1. The number of untripped flowers on the raceme.
2. The number of flowers tripped by the machine.
3. The percent of flowers tripped.
4. The number of seed pods on each raceme.
5. The percent of all flowers that set seed pods.
6. The percent of the tripped flowers that set seed.
7. The average number of seeds per pod.
8. The yield of alfalfa seed in pounds per acre from the plots that it was possible to take yield samples from.

Information Concerning the Actual Tests

An attempt to test the K.S.C. Tripper was first made on July 6, 1953; however, it soon became apparent that the roller angle on the machine was incorrect for proper feeding of the alfalfa into the rollers. It was also discovered at this time that the rollers were not stable enough. One trial test of about 20 feet was made and then the machine was returned to the shops for modifications.

The rollers on the machine had been mounted in such a manner that the bottom of the rollers were about six inches in front of the top of the rollers. It had been thought that the alfalfa would feed into the rollers

better with them slanting in this direction. However, it was soon apparent that this angle was too great and the rollers were changed to a more nearly vertical position.

One other modification was made at this time. The one-half inch rods through the rollers were replaced with rods five-eighths of an inch in diameter. This modification greatly increased the stability of the rollers.

At the completion of these modifications our tests were resumed on July 10, 1953. The first test plot was treated with the Chepil Tripper. The treatment consisted of going over all alfalfa in the plot once with the beaters oscillating at 1118 beats per minute. The top of the beater blades was located about 16 inches above the ground, and since the blades were eight inches wide the bottoms were about eight inches above the ground. As the alfalfa in which we were working averaged about 12 inches in height this setting on the machine worked out the best. Nearly all the flowers were located at a height of from eight to 16 inches.

After the treatment there appeared to be some damage to the plants. Some stems were broken and some of the flowers were knocked off the racemes. The following morning this plot presented a very noticeable change in color. Most of the flowers appeared wilted and faded in color. The entire plot had the appearance of a field at the end of its blooming period. The alfalfa flower seems to wilt very fast after being tripped and in 24 to 48 hours after tripping they have curled up tightly. If the flower has been fertilized and is going to produce a seed pod it will curl very tightly around the center of the flower protecting the new seed pod. If the flower was not fertilized the petals merely curl up and then drop off onto the ground. In either case the flower looses its color very shortly after tripping.

On July 11, 1953, test plot two was treated with the Chepil Tripper. After tagging the 100 racemes and pulling off the tripped flowers and those too immature to be tripped, the plot was treated once over with the beaters oscillating at approximately 750 beats per minute. Less damage to the plants was apparent, but there seemed to be fewer flowers tripped due to the slower oscillation of the beaters. Test plot three was treated as a check plot. Test plot four was treated the same as test plot two with the addition of another similar treatment, ten minutes after the first treatment. There seemed to be only slightly more damage to the plants than when treated only once; however, the percentage of flowers tripped seemed to be no greater.

Test plot five was treated the same as plot four with the addition of a third treatment administered one week after the first two treatments. This treatment one week later proved to be detrimental as many of the seed pods that had been formed as a result of the treatments the week before were knocked off the racemes. Test plot six was treated as a check plot.

On July 12, 1953, test plots seven, eight, and ten were treated. The treatments of these plots were exact duplicates of the treatments on plots two, four and five. Plot nine was used as a check plot.

Test plots 11 and 12 were treated on July 13, 1953. The K.S.C. Tripper was used on these plots. The rollers were rotated at the same speed and powered by a belt drive from the ground wheel. The 100 racemes were tagged at random from the racemes located along a tightly stretched string that was placed through the center of the plot from one end to the other end. It was necessary to do this as the machine could only treat a small swath through the plot. By keeping the tagged racemes all in a narrow row it was

possible to make sure that all the tagged racemes passed through the tripping rollers as the machine traveled through the plot. Only one treatment was given the plots. Test plot 13 was used as a check plot.

On July 16, 1953, test plots 14, 15, 16, and 17 were treated. Plot 14 was a duplicate of plot two and plot seven. Plots 15 and 16 both received the same treatment which consisted of once over with the K.S.C. Tripper after the speed of the rollers had been changed. One roller was rotating at a slightly higher speed than the other one and both rollers were powered by a gear reduction system that was connected to the gasoline engine used to drive the blower. This resulted in a rubbing action as well as in a pressing action on the flowers as they passed through the tripping rollers.

Test plot 17 was treated the same as test plot one which consisted of once over with the Chepil Tripper with the beaters oscillating at the higher speed of 1118 beats per minute.

INTERPRETATION OF THE RESULTS OF THE MECHANICAL TRIPPING TESTS

Chepil Tripper

The results of the mechanical tripping tests are shown in Table 1. Of the four different treatments by the Chepil Tripper, the treatments on plots one and 17 seemed to be the best. This treatment consisted of once over the plot with the beaters oscillating at the higher speed. An average of 49.15 percent of the flowers were tripped and 48.85 percent of the tripped flowers set seed pods that contained an average of 3.52 seeds per pod.

Although these plots showed up the best, there appeared to be some mechanical injury to the plants during this treatment. Some of the flowers were knocked off the racemes and some of the stems were broken. This

Table 1. Tripping efficiencies of the machines shown in percentages.

Plot	Treatments	Percent of flowers tripped	Percent of all flowers setting seed pods	Percent of tripped flowers setting seed pods	Average number of seeds per pod
1, 17	Chepil Impact Machine - Once over at 1118 R.P.M.	49.15	24.25	48.85	3.52
2, 7, 14	Chepil Impact Machine - Once over at 750 R.P.M.	47.15	25.40	54.05	3.28
4, 8	Chepil Impact Machine - Twice over at 750 R.P.M. 10 minutes between treatments	40.60	20.30	50.00	3.20
5, 10	Chepil Impact Machine - Twice over at 750 R.P.M. 10 minutes between treatments An additional treatment one week later	39.90	26.20	65.70	2.45
11, 12	K.S.C. Roller Machine - Once over with rollers turning slightly faster than ground speed. Both rollers turning at the same speed and being driven from the ground wheel.	34.45	21.05	62.35	2.45
15, 16	K.S.C. Roller Machine - Once over with rollers turning considerably faster than ground speed. Rollers turning at different speeds and being driven from the engine.	54.75	27.15	50.10	2.85
3, 6 9, 13	Check Plots		12.70		3.65

treatment still appeared the best; even with the injury to the plants.

The treatment on plots two, seven and 14 showed up very nearly as well. This was the same treatment as described above except the beaters were oscillating at the slower speed of approximately 750 beats per minute. An average of 47.15 percent of the flowers were tripped and 54.05 percent of the tripped flowers set seed pods that contained on the average 3.28 seeds per pod. The principle difference in the two plots was the number of seeds per pod. The first treatment averaged 3.52 seeds per pod against 3.28 seeds per pod from the second treatment. This figure is important because of the correlation between the number of seeds per pod and the amount of cross-pollination brought about. The naturally cross-pollinated seed in the check plots averaged 3.65 seeds per pod. It appeared then that the treatment with the beaters oscillating at the higher speed of 1118 beats per minute accomplished more cross-pollination. Since nearly all of the mechanical trippers that have been tested have failed because of the lack of sufficient cross-pollination, the fact that the Chepil Tripper brought about such a high number of seeds per pod seemed very much in its favor. There was very little difference between the 3.52 seeds per pod from the Chepil Tripper and the 3.65 seeds per pod from the naturally cross-pollinated check plots.

The results from the above described treatments were so close that the best treatment may hinge upon the fact of mechanical injury. There was more injury to the plants when the beaters were oscillated at the higher speed. More research over a longer period of time will be needed to find out just how much effect this injury may have on the alfalfa.

As additional treatments were added to the plots the efficiency of the machine decreased. The results definitely show that the best treatment with

this type of machine consisted of treating only once. The additional treatments seemed to do more harm than good. It appeared that the machine knocked off and damaged more flowers than it tripped on the second time over. Where the plots were treated twice over with 10 minutes between treatments 40.60 percent of the flowers were tripped, 50.00 percent of the tripped flowers set seed pods and these seed pods contained an average of 3.20 seeds per pod. The lower tripping percentage was due to the fact that many of the flowers that were tripped the first time over were knocked off the racemes by the second treatment. The plots that were treated three times with 10 minutes between the first two treatments and the third one a week later showed up with a still larger decrease in tripping percentage. These plots averaged 39.90 percent of the flowers tripped, 65.70 percent of the tripped flowers set seed pods and these seed pods averaged only 2.45 seeds per pod. The additional treatments then tripped very few flowers for the additional injury they brought about. This resulted in what appeared to be actually lower tripping percentages because some of the flowers tripped in the first treatment were knocked off the racemes by the second treatment.

K.S.C. Tripper

Plots 16 and 17 show better results than plots 11 and 12. Plots 11 and 12 were treated once over with the K.S.C. Tripper when the tripping rollers were rotated at the same speed and powered from a drive connected to a ground wheel. Plots 16 and 17 were treated once over with the K.S.C. Tripper when the tripping rollers were rotated at slightly different speeds and were powered by a drive from a gear reduction system connected to the gasoline engine. When the tripping rollers were powered from the engine, the tripping

percentage increased. The number of seeds per pod was also increased from 2.45 to 2.85. The fact that a rubbing action as well as a pressing action was placed on the flowers as they passed between the rollers, when the rollers were driven at different speeds, seemed to be the main reason that the tripping efficiency was increased by over 20 percent.

The cross-pollinating effect does not seem to be quite as high on this machine as on the Chepil Tripper as evidenced by the number of seeds per pod. One beneficial effect of this machine over the Chepil Tripper was the fact that there was little or no injury to the plants or flowers during treatment by the K.S.C. Tripper.

In test plots 11 and 12 an average of 34.45 percent of the flowers were tripped with an average of 62.35 percent of the tripped flowers setting seed pods. The number of seeds per pod was very low with an average of 2.45. In test plots 15 and 16 an average of 54.75 percent of the flowers were tripped. This was an increase of over 20 percent in tripping efficiency. An average of 50.10 percent of the tripped flowers set seed pods and these seed pods contained on the average 2.85 seeds per pod.

When the tripping rollers were power driven and rotating at different speeds, the K.S.C. Tripper showed the highest tripping percentage of the two machines. It was thought at the time of the treatments that, if this machine would have been larger and taken a larger swath so that it would have been easier to insure that all the tagged racemes in the plot passed through the rollers, the tripping percentage would have been still higher.

Plots 3, 6, 9, and 13 were used as check plots. One hundred racemes were tagged and the tripped and immature flowers pulled off in each plot. The tagged racemes were harvested when the tagged racemes in the test plots

were harvested. The number of seed pods and the number of seeds per pod were determined and recorded. An average of 12.70 percent of the flowers left on the racemes set seed pods. These seed pods averaged 3.65 seeds per pod. The high number of seeds per pod emphasize the efficiency of the bees and other natural tripping agencies with regard to cross-pollination.

Due to the small size of the K.S.C. Tripper it was impossible to take accurate seed yield data from the plots. An attempt to take seed yield data from hoop samples (1/1000 of an acre) in the plots treated by the Chepil Tripper and in the check plots did not work out satisfactorily. There seemed to be no correlation between the seed samples. On the basis of the tripping percentage, seed setting percentage and number of seeds per pod, a theoretical yield was computed in seeds per 1000 flowers in the plots. The results are presented in Table 2.

Table 2. Theoretical seed yields in seeds per 1000 flowers.

Plot	Percent of flowers setting seed pods	Number of flowers setting seed pods	Average number of seeds per pod	Seed yield in seeds per 1000 flowers
1, 17	24.25	242.5	3.52	853.60
2, 7, 14	25.40	254.0	3.28	833.12
4, 8	20.30	203.0	3.20	649.60
5, 10	26.20	262.0	2.45	641.90
11, 12	21.05	210.5	2.45	515.73
15, 16	27.15	271.5	2.85	773.78
3, 6, 9, 13	12.70	127.0	3.65	463.55

From the computations in Table 2, it can be seen that the check plots averaged only 463.55 seeds per 1000 flowers whereas all of the treated plots were higher. The highest yield was once over with the Chepil Tripper with the beaters oscillating at the higher speed. This treatment theoretically produced nearly twice the seed that would have been received from the untreated check plots. There was an increase of from 463.55 seeds to 853.60 seeds or an increase of 390.05 seeds which was an increase of 84 percent. The highest yield from the K.S.C. Tripper was on plots 15 and 16 where the alfalfa was treated once over with the rollers power driven and rotating at different speeds. The yield was computed at 773.78 seeds per 1000 flowers as against the check plot yield of 463.55. This was an increase of 310.23 seeds or an increase of 67 percent. The lowest yield for a treated plot was 515.73 seeds per 1000 flowers which is still an increase of 52.18 seeds per 1000 flowers in the plot.

INVESTIGATION OF THE NUMBER OF POLLEN GRAINS MADE AVAILABLE FOR CROSS-POLLINATION BY THE MACHINES

Equipment Used to Determine the Number of Pollen Grains Distributed by the Machines

The Chepil Tripper was used without any modifications. The K.S.C. Tripper was modified by cutting a small door in the side of the pollen chamber. This door was approximately the same height above ground as the top of most of the alfalfa flowers. The door was hinged and a mount was constructed on it so that a glass slide could be fastened to it. When the door was closed the glass slide was in the center of the air chamber directly above the top of the alfalfa flowers.

Regular one inch by three inch glass slides were used in this experiment. The slides were coated with white petroleum jelly and then wiped with a clean dry cloth. This left a very light layer of the petroleum jelly on the slides. An ordinary stop watch was used to time the length of exposure. The number of pollen grains on the glass slides were counted with the aid of a metallograph in the Industrial Engineering Department's Metallurgy Laboratory. This machine proved very satisfactory for this type of work. The direct lighting system made it easier to count the grains. Also the machine was equipped with a traversing mechanism on the platform that made it possible to take readings at spaced intervals across the slide.

Procedure in Determining the Number of Pollen Grains Distributed by the Machines

After a few test slides were taken to determine the best procedure, it was decided to take five slides from each machine every two hours during the day. These readings were taken at 8:30 A.M., 10:30 A.M., 12:30 P.M., 2:30 P.M., and at 4:40 P.M. for the three days of the tests. No readingswere taken at 4:30 P.M. on the first day of the test. It was hoped that by taking these readings at different times of the day it would be possible to determine if one part of the day might be more favorable for tripping the flowers.

The counts were taken at five centimeter intervals by traversing the length of the slide using the hand screw on the metallograph to move the slide across the lens. Fifteen counts were made on each slide. The area of the field in the metallograph upon which the counts were made was then converted to square inches and the number of pollen grains recorded per square inch after each reading.

All of the slides were exposed in the machines for a period of five seconds while the machines were traveling at a normal rate of speed through the alfalfa field. On the K.S.C. Tripper the slides were mounted in the center of the air chamber or pollen chamber. On the Chepil Tripper the slides were exposed by being held directly behind the beaters or blades as they oscillated back and forth at normal running speed. All of the pollen counts were made with the Chepil Tripper beaters oscillating at the slower speed of 750 beats per minute rather than at the higher speed of 1118 beats per minute.

INTERPRETATION OF THE RESULTS OF THE POLLEN GRAIN EXPERIMENT

The number of pollen grains being distributed by the machines was larger than had been anticipated. The information obtained by this experiment is shown in Table 3.

Table 3. The number of pollen grains per square inch distributed by the mechanical trippers during a five second exposure at different times during the day.

Time of day	K.S.C. Tripper			Chepil Tripper		
	22 July	24 July	27 July	22 July	24 July	27 July
8:30	412.9	238.2	276.4	730.4	1816.2	1768.5
10:30	325.4	248.7	312.2	650.5	2244.5	1672.7
12:30	392.8	331.4	391.8	2513.1	1095.6	2493.1
3:30	697.5	449.9	490.0	3852.8	1630.4	2413.7
4:30		307.2	487.0		2199.2	1365.6

The pollen counts on the slides taken from the Chepil Tripper were very much higher than those taken from the K.S.C. Tripper. However, it was noted

EXPLANATION OF PLATE VIII

Plate VIII shows the pollen grains as they appeared on the slides as the pollen counts were being made.

A. A single pollen grain magnified 662 times natural size.

B. A mass of pollen grains which have not been separated from each other magnified 662 times natural size.

PLATE VIII

that on the slides taken from the Chepil Tripper the pollen grains were in a great many cases, still bunched together as though the pollen mass from the flower had not been broken up. The slides from the K.S.C. Tripper, on the other hand, showed that the pollen masses had been broken up, as nearly everyone of the pollen grains were separated. Plate VIII shows the pollen grains as they appeared on the slides as the pollen counts were being made.

The results of these tests seem to support the theory that alfalfa flowers are more easily tripped during the warmest part of the day. In general, our pollen counts were low in the morning, high in the middle of the day and early afternoon, and low again late in the afternoon.

It is possible to believe that the K.S.C. Tripper may cross-pollinate nearly as well as the Chepil Tripper even though it does not transport as much pollen. The K.S.C. Tripper scatters each mass of pollen it transports, whereas, the Chepil Tripper transports a large amount of pollen in masses or bunches. A large mass of pollen on one flower will still pollinate only one flower, but if that mass were broken up into individual pollen grains it would be possible to pollinate several flowers with it.

INVESTIGATION OF THE VIGOR OF THE ALFALFA PLANTS PRODUCED FROM THE SEED HARVESTED FROM THE TREATED PLOTS

The seed that was harvested from the racemes that were tagged in the field and tripped by the machines, was planted in the greenhouse and allowed to germinate. At six weeks of age the plants were inspected for vigor or lack of vigor. When compared with plants produced from normally cross-pollinated seed, the experimental seedlings showed no effect of self-pollination. Neither was it possible to distinguish between plants from plots treated by the K.S.C. Tripper and plants from plots treated by the Chepil

Tripper. The stand, size of plants, amount of foliage, root system and color of plants compared very favorably with plants from normally cross-pollinated seed. Plates IX and X show the experimental plants at six weeks of age. Since it has been proven that there is a very marked decrease in vigor due to self-pollination it was assumed that the seed from plots treated by both machines was adequately cross-pollinated to prevent loss of vigor.

EXPLANATION OF PLATE IX

Plate IX shows the seedling plants produced in the greenhouse by planting the seed from the tagged racemes in the test plots. A thick stand of plants in each row indicate that the plants did not lack in vigor or vitality.

PLATE IX

EXPLANATION OF PLATE X

Plate X shows the seedlings produced in the greenhouse at 6 weeks of age. The plants showed no evidence of self-pollination as indicated by vigor. There was no difference between the plants grown from seed produced on the plots treated by the impact machine and the plants from seeds produced on plots treated by the roller machine.

PLATE X

SUMMARY

The practicality of using mechanical trippers to trip and cross-pollinate alfalfa flowers for increased seed production is not fully established. However, the following observations and conclusions are drawn from the analysis of the research presented in this thesis.

1. Alfalfa flowers can be tripped by mechanical trippers in sufficient quantities to increase the seed yield over natural tripping means if adequate cross-pollination can be provided.

2. Both the impact type tripper, referred to in this thesis as the Chepil Tripper, and the roller tripper referred to as the K.S.C. Tripper, satisfactorily tripped alfalfa flowers.

3. Mechanical trippers should be used when the field is at its peak in the blooming period because it is not possible to treat the flowers more than once without decreasing the yield.

4. The mechanical trippers should be used during the hottest part of the day and on a day that is bright, sunny and hot, if possible. The alfalfa flowers trip more easily under these conditions.

5. Adequate means of cross-pollination must be provided if the machine is to increase the yield satisfactorily. Self-pollination reduces the seed yield and lowers the vigor of the seed produced.

6. Mechanical trippers will probably prove economical only during the years of poor weather for insect activity or in large fields with relatively low insect populations and activity.

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MECHANICAL TRIPPING OF ALFALFA FLOWERS

by

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Determining the best method of harvesting legumes is an important step in seed production. However, the best method of harvesting that has ever been devised will do very little good if there is no seed to harvest.

Variability in seed setting continues to be the greatest problem in alfalfa seed production in the State of Kansas. Since alfalfa seed production is important in large areas of Kansas and since information on mechanical tripping was lacking for this area, a study was undertaken to determine the effectiveness of mechanical tripping.

Most people do not realize that when they look out across an alfalfa field, purple with bloom, that the functional part of the flower is not necessarily open. Alfalfa will set very little seed without cross-fertilization and practically no cross-fertilization can take place until this closed part of the flower is also opened. The sexual column of the flower is held under tension by a surrounding petal and when it is released, it springs out with such force against the open part of the flower that the whole procedure is known as tripping. Now, this brings about the question of how to trip these flowers so that fertilization may take place.

We have had to depend mainly on the bees to carry out this operation for us. As the bee inserts its head into the flower to collect nectar, it accidentally trips about two percent of the flowers it visits. If the bee population is high and the weather is good for insect activity, there is no problem of getting the flowers tripped. However, it is known that these favorable combinations of bees and weather do not always exist in Kansas during the blooming period.

If a machine could be constructed in such a way that the alfalfa flowers could be tripped and cross-pollinated by it, the alfalfa seed producers

could depend on getting a seed yield during the years of bad weather and poor insect conditions as well as in the good years.

Several mechanical trippers have been constructed in the past but they have failed to be successful because they did not provide for sufficient cross-pollination. It does very little good to trip the flowers if they cannot be cross-pollinated. Self-pollinated flowers produce very little seed and this would not be desirable even if it could be obtained, as it lowers the vigor and decreases the production of forage as well as the production of seed. In a normal field of alfalfa as high as 95 percent or more of the seed produced may be cross-pollinated. For these reasons mechanical tripping has never been advised.

A mechanical tripper was constructed here in the Agricultural Engineering shops last summer and tested along with a privately constructed machine on a field of Buffalo Alfalfa on the Agronomy Farm. Several plots six feet wide and 100 feet long were staked out and in each plot 100 racemes, from which all pods, tripped flowers and buds were removed were tagged. This left only untripped mature flowers on the racemes. The total number of flowers was recorded on the tag and immediately after a treatment the flowers tripped by the machine were counted and the number recorded on the tag. All untripped flowers were removed from the raceme. One week later the number of seed pods on each raceme was counted and recorded on the tag. All the tagged racemes were harvested and the number of seeds per pod was recorded.

The most favorable treatment with the K.S.C. Tripper consisted of once over the plot with the two rollers turning slightly faster than ground speed and with the rollers turning at different speeds. The rollers turning at different speeds imposed a rubbing action as well as a pressing action on

the flowers as they passed between the rollers. The machine tripped 54.75 percent of the flowers and 50.1 percent of the tripped flowers set seed pods that averaged 2.85 seeds per pod.

The most favorable treatment with the privately built, impact type Chepil Tripper consisted of once over the plot with the beater blades oscillating at 1118 R.P.M. The machine tripped 49.15 percent of the flowers and 48.85 percent of the tripped flowers set seed pods. These seed pods contained an average of 3.52 seeds per pod which compares very favorably with the 3.65 seeds per pod on naturally cross-pollinated alfalfa flowers.

It was not possible to take seed yield tests on the plots tripped by the K.S.C. Tripper because the machine treated such a narrow swath through the plot. An attempt was made to determine seed yields in the plots treated by the Chepil Tripper but the results did not prove satisfactory. Hoop samples of 1/1000 of an acre were taken but the results could not be correlated properly.

Several tests were made to determine the amount of pollen being distributed by the machines. Glass slides covered with a thin layer of petroleum jelly were exposed in the area in which the machines did their cross-pollinating while the machines were traveling through the field. Pollen counts were made on these slides with the aid of a microscope. The results showed that the Chepil Tripper was transporting more pollen in the vicinity in which the flowers were being tripped than was the K.S.C. Tripper.

It was concluded that both machines could satisfactorily trip alfalfa flowers and that both machines were cross-pollinating a large percentage of the flowers that were tripped and set seed pods. The Chepil Tripper possibly accomplished slightly more cross-pollination but the K.S.C. Tripper

tripped the highest percentage of flowers.

The plants produced by planting seed from the treated plots showed no effects of self-pollination. From this it was concluded that the machines were producing seed of a comparable basis with normally cross-pollinated seed.

The use of mechanical trippers will probably be limited to years of poor insect activity and weather or to large fields located in areas of low insect population.